Estimation of Aerosol Direct Radiative Effects from Satellite and In Situ Measurements

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Ames researchers have combined measurements from satellite, aircraft, and the surface to estimate the effect of airborne particles (aerosols) on the solar radiation over the North Atlantic region. These aerosols (which come from both natural and pollution sources) can reflect solar radiation, causing a cooling effect that opposes the warming caused by carbon dioxide. Recently, increased attention has been paid to aerosol effects to better understand the Earth climate system.

The researchers started with aerosol amounts estimated using the advanced very-high-resolution radiometer (AVHRR) instrument aboard the National Oceanic and Atmospheric Administration-11 (NOAA-11) satellite. Expressed in terms of light attenuation, or "optical depth," these aerosol amounts had been derived by other researchers for cloud-free days during the four seasons. The Ames team combined the satellite-derived aerosol optical depths with other aerosol properties (size distribution, light absorbing fraction, dependence of optical depth on light color) determined by aircraft measurements in two coordinated field campaigns. The first campaign was the Tropospheric Aerosol Radiative Forcing Observation Experiment (TARFOX) that was carried out off the eastern coast of the United States over the North Atlantic in the summer of 1996. The other campaign was the Second Aerosol Characterization Experiment (ACE-2) that was carried out over the North Atlantic off the coasts of Europe and North Africa in the summer of 1997. Ames researchers played significant roles in both of these experiments.

Figure 1 illustrates the calculated aerosol-induced effect on the net solar radiative flux at the tropopause during winter, spring, summer, and fall. As shown, the average flux changes are –1.7, –4.8, –5.1, and –2.3 watts per square meter (W/m^2) for the winter, spring, summer, and fall respectively, –3.5 W/m^2 being the annual average. For aerosols with no absorption, the annual average is –4.8 W/m^2.

The researchers used the International Satellite Cloud Climatology Project (ISCCP) cloud frequency data to estimate the impact of clouds on the aerosol effects. In general, clouds reduce the aerosol effects by attenuating the sunlight so that less can be reflected by the aerosol. Figure 1 shows that the clouds reduce the aerosol effect such that the regional averages fall to –0.8 and –1.1 W/m^2 for the absorbing and nonabsorbing aerosol, respectively.

These aerosol effects can be compared to a positive flux change of about 2.5 W/m^2 caused by the increases of carbon dioxide and other greenhouse gases over the past century. Thus, the aerosol effects (which come from both natural and pollution sources) are comparable, but opposite in sign, to the greenhouse gas effects. As shown by figure 1(c), within the aerosol plume coming off the eastern United States, the cloud-free, summer aerosol effect exceeds the greenhouse gas effect. Note that all the flux changes described above are at the top of the troposphere (~10 kilometer (km) altitude). Other work by the Ames team shows that aerosol-induced flux changes at the Earth surface can be larger still.

Finally, the study compared the satellite-derived results to those of previous studies that used chemical transport models. Although the methodologies have significant differences, the results of the study appear to agree with recent estimates from the chemical transport models.

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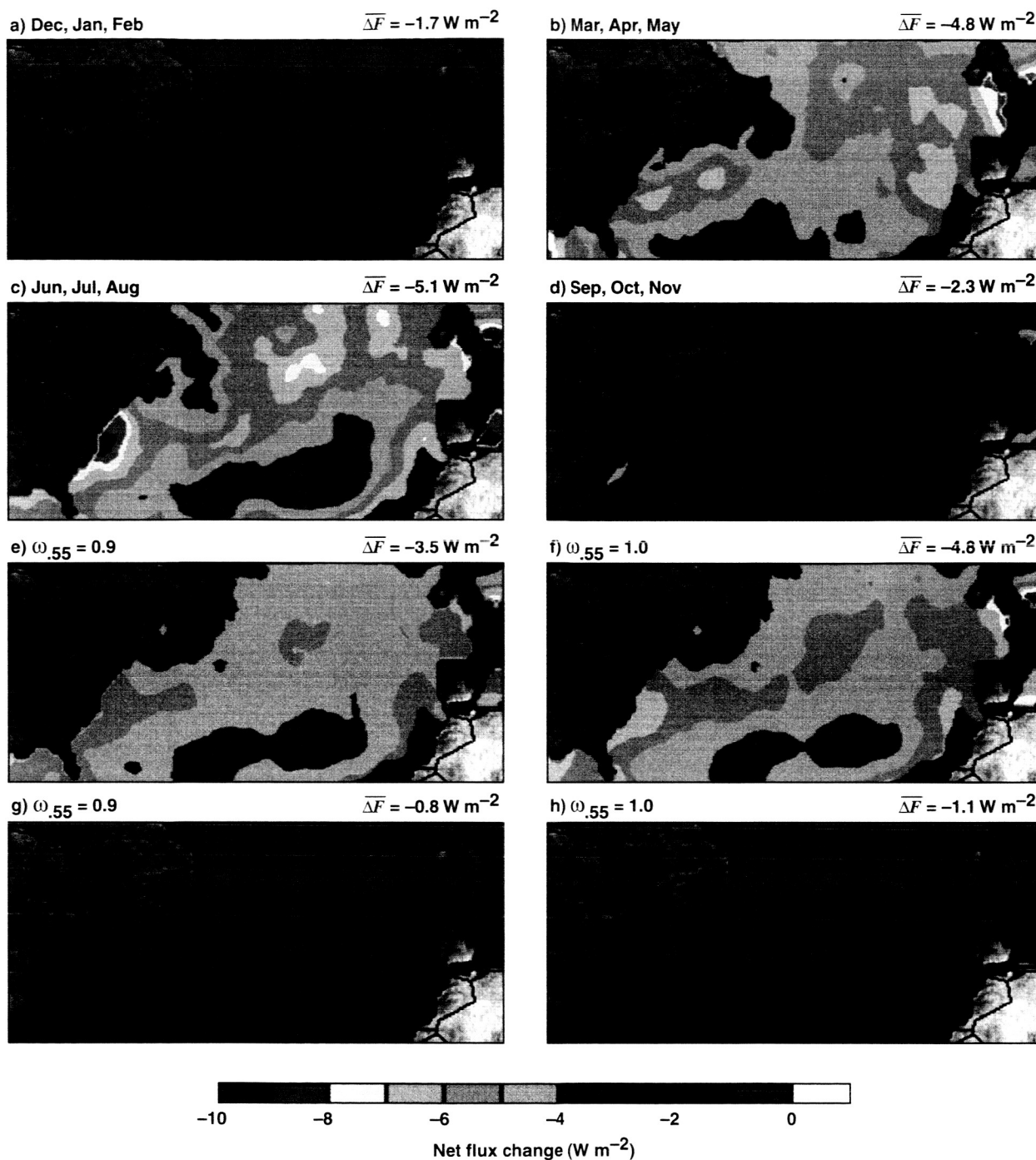**(650) 604-5404**
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Fig. 1. Aerosol-induced change in net shortwave flux at tropopause ($\lambda < 4$ μm). Results are based on AVHRR/ NOAA aerosol optical depths (AODs) reported by Husar et al. [1997] for the period July 1989–June 1991. The aerosol model uses a typical column size distribution from TARFOX. Values above each frame are averages for the 25° to 60° N region, excluding African dust. (a–d) seasonal average with single scattering albedo $\omega(550)$ = 0.9; (e–f) annual average (no clouds) for $\omega(550) = 0.9$ and $\omega(550) = 1.0$; (g–h) annual average (ISCCP clouds).